Remarks:

Acceptance of this responsive amendment as well as reconsideration and withdrawal of all of the presently outstanding rejections and an early allowance of the above-identified application is respectfully requested.

By this amendment, claims 1-22 remain pending of which claims 1, 3, 5-7, 9, 13, 15, 18 and 19 are currently amended and, moreover, dependent claim 4 stands withdrawn for purposes of examination.

Each of the independent claims 1, 5, 9 and 15 was amended in consideration of further highlighting the particularities of the invention claimed including in terms of more particularly highlighting the patentable differences of the subject matter covered by the present claims over that previously known including over the art documents as cited in the presently outstanding rejections. For example, with regard to base claim 1, the added impurity element exists (in the device) as a component (i.e., a constituent element) of a compound of the pure metal (of the upper capacitor electrode) which covers the polycrystalline grain surface of that pure metal. An example discussion of this is given on page 13, beginning in line 1, of the original Specification. Although this discussion is in connection with employing platinum as the base material of the upper capacitor electrode, other such metal material is applicable such as ruthenium, iridium, palladium and nickel, etc., as well as alloys such as discussed in connection with the example embodiment shown in Fig. 16 of the drawings, although not limited thereto (see the discussion beginning from the bottom of page 31 of the Specification to the end of the first paragraph on page 35 thereof and, in particular, note the discussion in the second paragraph of page 34 thereof).

With regard to the example Fig. 14 embodiment, the Specification states that lead (Pb) added to the upper electrode platinum layer 104 is precipitated at grain boundaries of the platinum layer to form a platinum compound in such a manner as to cover crystal grains of platinum. By thus adding lead (Pb) as an impurity to the platinum (Pt) layer 104, occurrence of active hydrogen due to the decomposition of hydrogen on the surface of platinum during heat treatment can be suppressed and, hence, deterioration/peeling at the interconnection formation step of the capacitor dielectric insulators (oxide high-dielectric-constant or ferroelectric thin film) can be prevented thereby enhancing the long-term reliability of the capacitor. (Page 29, the discussion beginning on line 16 thereof, as well as on page 33, the second paragraph thereof, etc., of the Specification.) Similar such revisions were implemented in each of the other independent claims 5, 9 and 15.

Independent claim 6 was amended for purposes of effecting clarification therein. That is, the last portion of the "wherein" clause was amended to highlight the fact that it is the resulting compound of the metal associated with the upper metal electrode of the capacitor structure that leads to suppression of the catalytic activity of the metal. Other revisions of a minor formal nature were also implemented. For example, in independent claim 1 as well as in the corresponding dependent claim 3 thereof, the expression "upper electrode" was revised to the expression upper capacitor electrode, consistent with the originally recited expression in independent claim 1. In independent claim 5, the expression "upper electrode" was likewise amended to read as upper capacitor electrode, consistent with the expression "lower capacitor electrode," recited earlier in that

claim. With regard to independent claim 6, the additional revisions therein are of a minor clarifying nature. With regard to dependent claim 7, the expression "said electrode metal" was changed to the expression said metal of the upper electrode in order to be more consistent with the related expression in the base claim 6 thereof. Regarding independent claim 9, moreover, two grammatically correcting revisions were implemented therein. In claim 13, an appropriate punctuation mark was inserted therein. With regard to claims 18 and 19, the multiple claim dependency thereof were changed to that of a single claim dependency format.

Discussion will now turn to the art rejections.

According to the outstanding Office Action, claims 1, 2 and 6 were rejected under 35 USC §102(e) as anticipated by Suzuki (USP 6,151,240); claims 6 and 8 were rejected under 35 USC §102(e) as anticipated by Okudaira et al (USP 6,078,072); claim 3 was rejected under 35 USC §103(a) over Suzuki; claims 5 and 7 were rejected under 35 USC §103(a) over the combination of Okudaira et al, *supra*, in view of Bonzel et al; and claims 9-22 were rejected under 35 USC §103(a) over the combination of Okudaira et al in view of Suzuki. It will be shown, hereinbelow, the invention according to the above-named claims, as now amended, was neither disclosed nor suggested by the above cited art in a manner as that alleged in the respective rejections. Therefore, insofar as presently applicable, these rejections are traversed and reconsideration and withdrawal of the same is respectfully requested.

The present invention is for a semiconductor device including a capacitor characterized in that an impurity is added to a metal in the formation of an upper

electrode (formed after formation of a high-dielectric-constant or ferroelectric film) of the capacitor, which leads to an action of suppressing the catalytic activity of the metal such as when the upper electrode is subjected to a hydrogen atmosphere during its manufacture. In the case of the upper capacitor electrode, use of platinum (Pt) is an example thereof, although not limited thereto, and as for the added impurity element thereto, lead (Pb), sulfur (S), selenium (Se), tellurium (Te), silicon (Si), boron (B), phosphorus (P), arsenic (As), bismuth (Bi) and barium (Ba) are examples thereof, although not limited thereto. As further examples of the main constituent metal element for the upper capacitor electrode, palladium, ruthenium, iridium and nickel may be substituted therefor in place of platinum and with a similar advantageous result being achieved (page 12, lines 8-20 as well as Table 2 on page 13 of the Specification, the latter showing examples of formed compounds of platinum with regard to the upper capacitor electrode.)

The addition of the impurity element in the formation of the compound of the pure metal in the formation of the upper capacitor electrode according to the present invention requires a relatively low solubility in the metal, preferably, less than 10 atom%. As a result, therefore, when, for example, platinum is crystallized into a polycrystalline state at the step of depositing a platinum layer or at the step of heat-treating the platinum layer after depositing the same, most of the additional impurity added (e.g., Pb, etc.) leads to the formation of a compound of the pure metal such as platinum which covers the surfaces of polycrystalline grains of that pure metal (e.g., platinum), etc. The catalytic activity on the surface of that pure metal (e.g., platinum) is thus lowered. Therefore, upon heat-treatment in, for example, a hydrogen atmosphere, occurrence of active hydrogen due to the

decomposition of hydrogen on the surface of that pure metal (e.g., platinum), etc., is suppressed, and thereby the deterioration of the capacitor characteristics and the peeling of the electrode are also suppressed. Further, since the concentration of the impurity of the added element to the main metal element of the upper electrode is small, deterioration of the capacitor characteristics due to an increase in the electrical resistance of the entire platinum layer does not occur. This is similarly the case when using, instead of platinum as the upper electrode main component metal, palladium, ruthenium, iridium or nickel. (Page 13, line 1, to page 14, line 8, of the Specification.)

To reiterate, the present invention is particularly characterized by a scheme calling for the suppression of the catalytic activity of the metal element (i.e., pure metal) associated with the formation of the upper capacitor electrode, this being done by adding an additional impurity element thereto as that called for in each of claims 1+, 5, 6+, 9+ and 15+. Without the formation of such compound of the upper electrode pure metal, deterioration such as in connection with the oxide dielectric insulator film and thereby the overall characteristics of the capacitor including problems associated with peeling of the electrode occur. The present invention, on the other hand, promotes the suppression of such deterioration of the capacitor due to treatment, for example, in a hydrogen atmosphere which is performed after the upper electrode is formed. Accordingly, it is essential to apply to the main constituent element of the upper electrode an additional impurity element. The oxide high-dielectric-constant or ferroelectric film such as PZT or BST may be composed, although not limited thereto, in connection with the formation of capacitor such as in connection with a DRAM on an LSI substrate, as

one example. It is submitted, such a scheme as that presently called for in claims 1+, 5, 6+, 9+ and 15+ is a clear and patentable improvement over the teachings of the applied art in connection with the outstanding rejections. This is supported with the following discussion directed to the cited references.

According to Suzuki, as a material for an upper electrode, Suzuki disclosed using a Ba_2RuO_4, which is a layered perovskite oxide. (Column 2, lines 56-57, in Suzuki.) Suzuki intended to form a high-dielectric-constant capacitor constituted by a lower electrode, an upper electrode and a high-dielectric-constant or ferroelectric film therebetween, based on the principle that each layer is combined to maintain a lattice-matching with that of the silicon substrate through a buffer layer. (Column 9, lines 7-36, in Suzuki.) In order for Suzuki to be able to achieve this, the above-described perovskite structure is essential. Accordingly, the component ratio of the material of the Ba and Ru components of the above molecular compound formula in Suzuki is necessarily limited to Ba:Ru=2:1, which is in clear contradistinction with that presently called for.

In order to achieve suppression of the catalytic activity of the metal element (or pure metal) of the upper capacitor electrode, according to the present invention, the addition of the impurity element must necessarily lead to a small solubility in the pure metal used for the electrode. As explained earlier in these remarks, and, more extensively, in the original Specification, in order for this to occur, the concentration must necessarily be relatively small, preferably, less than 10 atom%. Insofar as applicable to the present invention, the ratio between that of Ba and Ru must necessarily be considerably weighted in favor of Ru. For example, when barium (Ba) is used as the added impurity in the mixture involving

ruthenium (Ru) or its oxide, in which Ru is the main (dominant) constituent element in the ratio, the ratio must preferably be less than 10 atom% in order to prevent an undue increase in the electrode resistance. (Page 14, line 18, to page 15, line 24, of the present Specification.) Such a small ratio is sufficient to cover the interfaces in connection with suppressing catalytic activity without the fear of unduly increasing the electrical resistance of the electrode material.

Suzuki, it is submitted, was only concerned with achieving a perovskite structure. That is, Suzuki neither discussed nor inferred the desire to prevent the increase of electrode resistance nor, for that matter, disclosed any specific specifications related to the level of impurity concentration for the purpose of suppressing the catalytic activity. It is submitted, there was no teaching or suggestion in that regard.

Regarding claim 3, the rejection, based on Suzuki, argues that "it would have been obvious ... to select the concentration of the impurity element ...[to achieve] optimum or workable ranges." Suzuki's structure, inherently, leads to a higher resistance with regard to Ba_2RuO_4 in comparison with that of the metal element Ru. According to the present invention, the structure calls for achieving an action of suppressing the catalytic activity of the metal element associated with the upper capacitor electrode. In that capacity, the additional element exists as a component of a compound of the pure metal covering a polycrystalline grain surface of the pure metal. As is supported by the original Specification, in order to achieve such suppression, without unduly raising the resistance, it is necessary for the concentration of the added impurity element to be considerably smaller than that taught by the constituent elements of Suzuki, as referred to above. Such

is in clear contradistinction with that taught by Suzuki. According to the present invention, moreover, a preferable atomic ratio level is set forth in claims 3, 12, 17 and 20. Further, in view of the required precise control for forming a perovskite structure for the electrode such as that taught by Suzuki, the manufacturing costs involved are also considerable.

Okudaira et al disclosed a scheme in which platinum (Pt), ruthenium (Ru) or iridium (Ir) containing oxygen may be inserted on the interface between a lower electrode and a dielectric film such as BST in connection with the ferroelectric capacitor. According to Okudaira et al, in order to prevent the peeling of a lower electrode, Pt, Ru or Ir containing oxygen are stacked on Pt, Ru, Ir, and so on. However, there is no disclosure in Okudaira et al, either by discussion or inference, regarding the prevention of catalytic activity resulting from the emergence of hydrogen from an upper capacitor electrode, in clear contradistinction with that presently called for with regard to each of the independent claims and, further, according to the corresponding dependent claims thereof.

In accordance with the present invention, by precipitating the impurity onto the surface of polycrystalline grains of the metal, reduction of the catalytic activity of the upper electrode is achieved, as was earlier discussed in these remarks and, as more extensively discussed in the present Specification (Page 13, line 1, to page 14, line 8, etc., of the original Specification.) Such, it is submitted, was not taught by Okudaira et al. It is submitted, Okudaira et al's structure does not have any effect that would lead to the suppressing of the catalytic activity of the upper electrode with regard to preventing the emergence of deterioration at the interface

at the upper electrode and the dielectric film of the capacitor.

Bonzel et al, it is submitted, disclosed that a sulfur action leads to an adhesion phenomenon of H_2S onto a surface of platinum (Pt). This is a published document of general interest only. Bonzel et al, similarly to Okudaira et al, neither disclosed nor suggested a device structure which is characterized by a reduction of catalytic activity by adding, for example, sulfur as the impurity onto an upper capacitor electrode composed of, for example, Pt, although not limited thereto, as presently called for in claims 5 and 7. As called for in base claim 5, for example, the upper capacitor electrode, which is provided on an oxide high-dielectric-constant or ferroelectric film, is subjected to a hydrogen atmosphere during manufacturing. Accordingly, the present inventors have discovered that by adding an impurity of an additional element to the platinum, which leads to the formation of a compound of said platinum covering the polycrystalline grain surface of the platinum, suppression of the catalytic activity of the platinum during its formation or thereafter is effected. Such was not taught by Bonzel et al nor, for that matter, could it have been achievable even in view of the combined teachings of the above referred-to cited references, in any combination.

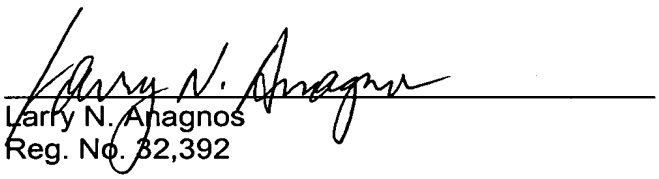
Therefore, in view of the above noted deficiencies in Suzuki, Okudaira et al as well in Bonzel et al, the invention according to claims 1+, 5, 6+, 9+ and 15+, could not have been rendered obvious therefrom, these references taken separately or in any combination. As was shown above, none of the references taught adding an impurity element into the metal component of the upper capacitor electrode in the manner to achieve suppression of the catalytic activity of the metal, the suppression being effected as a result of the formation of the

compound of the metal covering a polycrystalline grain surface thereof. In order to achieve this, the atomic ratio of the additional impurity element must necessarily be small and, preferably, less than 10 atom%. Such, it is submitted, could not have been achievable even over the combined teachings of Suzuki, Okudaira et al and Bonzel et al.

Therefore, in view of the Amendments presented hereinabove together with these accompanying remarks, reconsideration and withdrawal of the outstanding rejections as well as favorable action therefor on all of the presently pending claims and an early Notification of Allowability of the above-identified application is respectfully requested.

To the extent necessary, applicants petition for an extension of time under 37 CFR §1.136. Please charge any shortage in the fees due in connection with the filing of this paper, to the Deposit Account of Antonelli, Terry, Stout & Kraus, LLP, Dep. Acct. No. 01-2135 (520.37607VX1), and please credit any excess fees to such deposit account.

Respectfully submitted,
ANTONELLI, TERRY, STOUT & KRAUS, LLP



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